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The Relative Effect of Time of Reinforcement and Pre-Reinforcement Activity on the Learning of Meaningful Verbal Material

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THE RELATIVE EFFECT OF TIME OF REINFORCEMENT AND PRE-REINFORCEMENT ACTIVITY ON THE LEARNING OF MEANINGFUL VERBAL MATERIAL

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by
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The present study explored the effect of time of reinforcement and pre-reinforcement activity on human verbal learning. 143 college students were divided into 6 groups, each group receiving knowledge of results after 0 or 5 minutes. The time of reinforcement was taken in combination with one of three pre-reinforcement activities elicited by similar, dissimilar and no controlled stimuli presented during the delay interval. The groups receiving immediate reinforcement learned significantly better than those receiving reinforcement after 5 minutes. There was no differential effect due to the pre-reinforcement activities. However, the effect of the activities may have been masked by a number of factors. Further study appears necessary to better understand the effect of activities on delayed KR learning.

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Introduction

The optimal interval between response and reinforcement has been a major theoretical issue and a subject of periodic investigation during the last fifty years. It is stated in the third corollary of Hull's (1952) behavior theory that the reaction potential of an organism approaches its weakest point when the temporal interval between the response and reinforcement is about five seconds. Major theorists such as Thorndike (1931), Guthrie (1952), Hull (1943), and Skinner (1953) advocate the superiority of immediate reinforcement and the majority of the empirical evidence derived from investigations with lower animals, tends to support the principle that learning varies inversely with the temporal interval between response and reinforcement.

Further support of the principle is given by Hilgard and Marquis (1961), concluding from the results of several animal studies, that

> Evidence of many kinds indicates that responses which are followed by reward immediately are learned more rapidly than responses for which reward is delayed . . . At the present time it seems unlikely that learning can take place at all with delays of more than a few seconds . . .

Brackbill, Wagner and Wilson (1964), commenting on Renner's (1964) review of 50 years of animal research, conclude that " . . . learning efficiency decreases the longer the

feedback delay . . . " and with a delay of a few seconds, learning may not occur at all.

Similar evidence has been derived from investigations dealing with human motor and verbal learning, where knowledge of results (KR) is used as reinforcement. Greenspoon and Foreman (1956) studied the effect of delayed reinforcement on a human motor task. The learning task in this study (1956) required blindfolded subjects to draw lines, three inches in length. After each response, the subjects waited zero, ten or twenty seconds before being informed of the correctness of their response. The results indicated that immediate was significantly superior to delayed reinforcement.

The investigations by Landsman and Turkewitz (1962) and Saltzman (1951) indicated that the principle also holds true in verbal learning tasks. In both studies, the subjects were required to discriminate between two choices of four place numbers and after each choice, either zero or six seconds elapsed before KR was presented to the subjects. The subjects that received KR after zero seconds, learned the discrimination task significantly better than the subjects receiving KR after six seconds.

The bulk of the supporting evidence has been derived from studies of lower animals with relatively few concerning humans; however, the applicability of this principle

has been extended to human learning. Munn (1966) states, on the recognition of this principle in present educational programs, that

> . . . it is a long way from shaping behavior of rats to teaching school subjects to children; yet this step has been taken by the teaching machines and learning programs so much in vogue today.

The teaching machine is an important aspect of a learning program in which the immediacy of reinforcement is one of the basic underlying principles. Skinner (1958) assumes that the use of this machine helps overcome the greatest disadvantage of our present classroom; the difficulty in providing prompt reinforcement. Sawrey and Telford (1964) conclude, in their textbook on educational psychology, that

> We know of no important exception to the generalization that the rate of learning is directly related to the immediacy, accuracy and completeness of one's knowledge of the results of his efforts in learning (researcher's italics).

The superiority of immediate reinforcement appears to be extended to all learning situations, however, the validity of such a generalization is questionable. The bulk of the investigations, exploring the effect of time of reinforcement on learning, direct their efforts to manipulating the temporal interval, per se, and relatively little emphasis has been placed on exploring other factors. The need to systematically explore a number of factors, in human learning situations, was indicated by Stevens (1951). Of specific value was Stevens' review on

retroactive inhibition which dealt directly with factors explored in the present investigation. Although retroactive inhibition studies investigate the effect of various factors on learning after learning is already assumed to have occurred, the need to study the influence of these factors on delayed reinforcement learning seems apparent.

The following review attempts to show the effect of some specific factors other than the temporal interval which seem essential to exploring and better understanding the relationship of time of reinforcement to learning. The factors considered in this review are: (1) human vs. animal learning, (2) the method in which learning is measured, and (3) the pre-reinforcement activity of the subject. Reference is also made relative to the ways in which these factors were included in the present investigation.

Animal vs. Human Learning

Renner's (1964) review on fifty years of delayed reinforcement investigations indicates that delay interferes with animal learning. However, the investigations with human subjects are not as conclusive. Alexander (1951), measuring the effect of delay on humans' learning a motor skill, found no evidence of differential learning due to the time of reinforcement. The investigation varied the delay interval in seconds (zero, two, four, eight and sixteen), but the subjects showed no significant differences

in learning a dart throwing skill. A line drawing task with delayed KR of zero, ten and twenty seconds had no significant effect on blindfolded subjects in Saltzman, Kanfer and Greenspoon's (1955) investigation. The results of investigations in human verbal learning have also resulted in similar outcomes. Bourne and Bunderson (1963) demonstrated that delayed KR of zero, four and eight seconds was an ineffective variable in the discrimination of geometric forms by college students. Noble and Alcock (1958), using delays of zero and three seconds, measured effect of KR on the discrimination learning of numbers and found no significant difference.

Further studies (Bilodeau and Bilodeau, 1958; Boulter, 1964; Brackbill and Kappy, 1962; Ryan and Bilodeau, 1962) on human motor and verbal learning problems show no difference in learning due to the time of reinforcement. The validity of the principle that delayed reinforcement has a decremental effect on human learning is further questioned from other studies (Brackbill, Isaacs and Smelkinson, 1962; Brackbill and Kappy, 1962; Brackbill, Bravos and Starr, 1962; Brackbill, Wagner and Wilson, 1964; Lavery and Suddon, 1962) which show a superiority of delayed over immediate reinforcement. Although the investigations of delayed reinforcement on human learning are inconclusive there appears to be a definite difference in the way it affects human as

compared to animal learning. It seems that the effect of delayed reinforcement on animals cannot be generalized to all human learning situations and the need for further study and exploration is apparent.

Criterion of Learning

The majority of the investigations (Landsman and Turkewitz, 1962; Boulter, 1964; Denny, Allard and Hall, 1960; Jones and Bourne, 1964; Saltzman, 1951) on delayed reinforcement use measures of acquisition as evidence of learning. The number of errors or the number of trials it requires a subject to attain a prescribed criterion is measured and evaluated. However, Brackbill, Wagner and Wilson (1964) stress the fact that for all practical purposes, it would be more worthy to investigate the effect of delayed reinforcement on retention. The authors feel that more emphasis should be placed on retention or " . . . teaching them so they stay taught . . . ," instead of on the sole process of acquisition.

Brackbill, Wagner and Wilson (1964) required third grade children to learn eighteen English words and their French equivalents, recording the number of errors and trials to reach a criterion. The difference between the immediate and ten second delay KR group was insignificant. However, when the same measures were taken again seven days later to determine how well the subjects were able to

relearn the material, the delayed KR group performed significantly better. Retention, the number of errors in relearning or the number of trials to relearn, has been used by a number of other investigators (Brackbill, Bravos and Starr, 1962; Brackbill, Isaacs and Smelkinson, 1962; Brackbill and Kappy, 1962; Brackbill, Wagner and Wilson, 1964; Lavery and Suddon, 1962) and the results indicate that delayed KR facilitates retention while immediate KR impairs retention.

However, it is the contention of the present investigator that it is difficult to assess whether the difference in retention is due to the delayed KR or to the fact that during acquisition, the subjects may have received the material to be learned an unequal number of times or length of presentation varied. The subjects receiving delayed KR in the study by Brackbill, Bravos and Starr (1962) and Brackbill and Kappy (1962) required more trials and errors to acquire the material to be learned and consequently were presented with the material to be learned a greater number of times than the subjects who learned more rapidly. The present study does not attempt to show how this variable affects learning; however, the possibility that it may influence the investigation is recognized and the present study eliminates this variable by designing the procedure so that each subject receives the learning material an

equal magnitude of time and only the temporal interval between response and KR is varied.

After the material has been presented equally to all subjects, a measure of acquisition may be taken; however, it is difficult to conceive of learning as only acquisition or as only retention, since one does not occur without the other. Therefore, the present study incorporates acquisition and retention into one measure of learning. The measure of acquisition and retention is derived from a test on the presented material twenty-four hours after the presentation period. This eliminates the separate measurement of acquisition and retention and also the questionable effect of measuring retention after an unequal number of acquisition trials; or, measuring acquisition with disregard for the possible effects of such variables as frustration and fatigue interacting with the number of trials and errors a subject requires for acquisition.

Pre-reinforcement Activity

The majority of the studies on lower animals reviewed by Renner (1964) demonstrates that learning efficiency decreases with increases in feedback delay; however, when an attempt is made to control for any mediating variables during the delay interval, the results are not as conclusive. Grice (1948), Perkins (1947), and Harker (1956) demonstrate the ineffectiveness of delayed reinforcement

due to the mediating of secondary reinforcing agents, and Renner (1963) concludes from his study " . . . that the temporal gradient of reinforcement is a function of drive level and availability of cues." In an unpublished study by Carlton, mentioned by Spence (1960), a confinement segment was devised in his apparatus for rats which " . . . would discourage turning away from the food-cup during the delay period and thus increase the likelihood of maintaining orientation toward it." This increased control of the rats' activity during the delay interval was shown to be a variable which significantly facilitated learning over the rats which were not confined.

The bulk of the studies (Alexander, 1951; Bilodeau and Bilodeau, 1958; Bourne and Bunderson, 1963; Brackbill, Isaacs and Smelkinson, 1962; Brackbill and Kappy, 1962; Brackbill, Wagner and Wilson, 1964; Greenspoon and Foreman, 1956; Landsman and Turkewitz, 1962; Noble and Alcock, 1958; Ryan and Bilodeau, 1962; Saltzman, 1951; Saltzman, Kanfer and Greenspoon, 1955) on delayed reinforcement appear to overlook the time interval between response and reinforcement for any possible effective variable other than the mere passage of time. The studies do not attempt to control for the subjects' activities or stimuli which may possibly be interferring with or facilitating learning. The studies appear to regard this period of time as a

vacuum or an interval where "nothing" impinges upon the subject. Obviously, such a state is not experimentally producible at the present and the variables that do occur during this interval of time must be controlled.

The results of Lorge and Thorndike's (1935) investigation indicated that it is not merely the passage of time which is the effective variable, but further consideration must be given to other variables that occur during the pre-reinforcement interval. Lorge and Thorndike (1935) required subjects to toss a ball at a target which they could not see. Information to the subjects, regarding the accuracy of their throw, was given immediately to some and after a short delay interval to the others. There was no difference in performance due to the time of KR. However, when the interval between throwing the ball and KR was filled with another throw, the gain in accuracy was impaired.

The importance of the delay interval for variables other than solely the passage of time was also indicated in the following studies. Jones and Bourne's (1964) study implied that delay was detrimental only as a function of successive items presented prior to KR. Ross, Hitherington and Wray (1965) demonstrated a poorer performance of children in a size discrimination problem due to the continual presence of the stimulus during the delay interval. They

attributed the effect to competing responses made during the delay interval. Hockman and Lipsitt (1961) " . . . supposed that effects of delayed reward are dependent upon the effective distinctiveness of the stimuli to be discriminated, or the difficulty of the task," and in their experiment merely decreasing the number of stimuli to be differentiated likewise decreased generalization among them and thus enhanced the learning rate. Similarly, Rieber (1961) hypothesized that the delay of reward in children facilitates the association of competing responses with the stimuli which elicit the conditioned response. Rieber (1961) concludes from the study that

> Hence, it would be expected that interference with the conditioned response would be an increasing function of the similarity between the cues present during the delay period and those which elicit the conditioned response.

Investigations, such as those mentioned in the previous three paragraphs appear to be approaching a new basis for the relationship between learning and delayed reinforcement. More emphasis must be placed on manipulating various activities during the delay interval rather than the manipulation of time, per se. The acceptance of such classes of activities as being the detrimental or facilitating variable affecting learning provides a stronger empirical and theoretical basis for the principle rather than the attribution of the delay effect to the

mere passage of time. The present writer agrees and desires to extend the suggestion of Noble and Alcock (1958) that

> Whether reward or information is withheld seems to be of less consequence than what the subject does during the time interval between response and after effect.

Major assumptions. Although relatively few studies deal with it specifically, investigators often attribute the results of their experiments to the delayed interval activity, and various assumptions have been made as to how it affects learning. Saltzman (1951), in a study described earlier, attributed the poorer performance of the delay group to their activity during the pre-reinforcement interval. The activity was rehearsal of the presented stimulus and since rehearsal was occurring prior to knowledge of the correctness of response, the incorrect response was reinforced as well as the correct one and thus interferred with acquisition. Brackbill, Bravos and Starr (1962), also assume that the rehearsal activity is the main variable in learning. However, it is their contention that these covert responses are being strengthened, due to the fact that the responses are followed by reinforcement. Immediate reinforcement is not as facilitating since reinforcement precedes rehearsal.

The results from an investigation by Sturgis and Crawford (1964) showed no differential effect in verbal

learning due to the time of reinforcement and it was, in fact, demonstrated in two of the four phases included in the study that delay is superior to immediate reinforcement. Sturgis and Crawford assumed that their investigation indicated the importance of the subjects' activity during the pre-reinforcement interval. It was not the original intention of the authors to direct the subjects activity during this pre-reinforcement interval, but they assumed that relevant mediating activity did occur due to the presentation of " . . . rather familiar, meaningful material of which [the subjects have] an adequate symbolic repertoire". " . . . mulling over the question and alternatives . . ." was stated as an example of the type of mediating activity that occurred during the delay interval and after such activity, they assumed that the feedback was more effective. The relative insignificant effect of immediate and delayed reinforcement on learning nonsense material was attributed to the possibility that the subjects formed a set to search for meaningful relationships. And as stated by the authors, this " . . . may have interfered with any advantage of immediate reinforcement and also rendered the subjects in a more receptive state for the delayed reinforcement on the following day."

Bourne (1957) demonstrated that as the length of

the delay interval increased, the level of performance proportionally decreased. Bourne's (1957) hypothesis was in accord with Spence (1947) and his statement that the stimulus associated with a response persists for a period of time and decays as a function of time. Therefore " . . . the length of delay in reinforcement over which learning can occur depends upon the rate of decay of this stimulus complex" and it was Bourne's assumption that increase in task complexity, by the presence of similar stimuli during the delay interval, leads to a higher decay rate. That is, Bourne suggests presenting subjects with stimuli of varying degrees of similarity to the patterns in the problem during the delay interval. These stimuli would then probably interfere with the stimulus trace of the original pattern to which the subjects responded and thus increase the effectiveness of delay as an inhibitor of performance.

Activity and human motor learning. Several studies (Bilodeau and Ryan, 1960; Bilodeau, 1956; Boulter, 1964; Lavery and Suddon, 1962) on human motor learning, deal specifically with the effect of controlled behavior during the delay interval. Bilodeau and Ryan (1960), Bilodeau (1956) and Lavery and Suddon (1962) varied the number of stimuli presented between the original stimulus (S_1) and the reinforcement (R_1). The subjects, therefore, had to

concentrate on S_2, S_3, . . . , S_n, before receiving reinforcement, R_1, for S_1. Bilodeau and Ryan (1960) showed no difference in acquisition and Bilodeau (1956) and Lavery and Suddon (1962) demonstrated a decrease in learning with increasing delay, however, Lavery and Suddon's (1962) delay group retained the skill better. Greenspoon and Foreman (1956) contend that in their study delay was detrimental because the subjects are being reinforced for different "hand-maintaining" activities rather than the response to be learned. A replication of this study by Bilodeau and Ryan (1960) demonstrated no difference in learning due to the type of "hand-maintaining" activity during the delay interval. Boulter (1964) used five different types of activity during the delay interval and found no significant difference in acquisition. In summary, studies on human motor learning show no conclusive facilitating or detrimental effect due to activities during the delay interval.

Activity and verbal learning. Champion and McBride (1962) and Jones and Bourne (1964) studied the effect of delayed reinforcement on human verbal learning, emphasizing control on the subject's activity during the delay interval. Champion and McBride (1962) investigated the effect of activity during the delay interval on the learning of associated word pairs. The subjects were presented with a word and were required to learn the respective

associated word pair. During the two or five second delay intervals, the subjects read aloud words associated to the stimuli. The latency time was recorded in seconds and used as the measure of learning. This study (1962) indicated that similar activity during the delay of reinforcement interval impairs learning. Champion and McBride concluded that their study confirms Spence's (1947) hypotheses that " . . . the main effect of delayed reward [is] the incompatible responses which might occur in the delay period and subsequently compete with the instrumental response."

Champion and McBride (1962) used latency as the measure of learning, but the validity of these results extrapolated to other situations where a different criterion for learning is used has not been investigated. The present study explores further the effect of similar activity during the pre-reinforcement interval, using acquisition and retention as the criterion of learning.

Spence's (1947) hypotheses are further supported by Jones and Bourne's (1964) paired association study, demonstrating that the rehearsal of irrelevant activity during the delayed reinforcement interval interferes with performance or acquisition. The subject's task was to discriminate between two four-digit numbers with an interval of zero or six seconds before presentation of KR. The difference in acquisition between the immediate and the delayed KR group

was insignificant. Jones and Bourne then replicated their study in all exactness except for the verbal instructions to the subjects and the results indicated a superiority of immediate reinforcement. They attributed the difference to the irrelevant activity propagated by the verbal instructions. The instruction given in the first experiment was to identify the correct number; in the second experiment, the instruction was to memorize the numbers in addition to locating the correct number. It was their assumption that the subjects in the latter experiment concentrated primarily on memorizing the numbers and thus interfered with the acquisition of the choice responses.

It is questionable whether the subjects in Jones and Bourne's study were primarily occupied with the irrelevant activity or with the response to be learned since the opportunity to do either was present. There is also some question as to the irrelevancy of the activity since memorizing the numbers included memorizing the correct as well as the incorrect response. In the present study, the material to be learned is not presented during the interval of time that irrelevant activity is supposed to be taking place. This eliminates the opportunity for rehearsal of the correct response during the irrelevant activity interval where only the rehearsal of the incorrect response should be occurring.

To investigate the effect of activity during the delay interval, Jones and Bourne attempted to control the subjects delay interval behavior by presentation of successive stimuli during the pre-reinforcement interval. In this paired association study, using 16 nonsense trigrams, zero, two, four and eight successive stimuli were introduced in the delay interval. The group receiving eight successive stimuli before KR learned with the least errors and trials; the group with four stimuli had the most trials and errors. However, an additional part of the study indicated that the form of reinforcement, whether it was presented with correct response only or with the correct stimulus and response made a significant difference. In the case where the correct response was presented alone, the increase in successive stimuli led to an increase in error.

The present writer questions the use of KR in the form of the stimulus and response since with the restatement of the original stimulus and response, there is not a temporal interval between the response and reinforcement and it is as if immediate reinforcement takes place. The present study presents the KR in the form of the correct response only.

The studies by Champion and McBride (1962) and Jones and Bourne (1964) indicate that activity during the pre-reinforcement interval is decremental to learning.

However, these studies (1962, 1964) used the rote memorization of word pairs and four digit number pairs as the learning task. The generalization from such a task to the type of learning that is normally performed in the classroom is questionable. The understanding of general principles and the ability to summarize them in one's own words appears to be a more important goal in our educational endeavors and it is the purpose of the present study to measure the effect of delayed reinforcement on the learning of principles.

The length of the delay interval in the study by Champion and McBride (1962) and Jones and Bourne (1964) and others (Brackbill and Kappy, 1962; Bourne and Bunderson, 1963; Bourne, 1957; Denny, 1960; Lipsitt, Castaneda and Kemble, 1959) are varied in units of seconds. Champion and McBride (1962) used two seconds and five seconds and Jones and Bourne (1964) used a delay interval of six seconds. It is assumed by the present author, that the activity during the pre-reinforcement interval is the effective variable that facilitates or retards learning. It seems that the type and amount of activity that can occur within two or five seconds or between zero and two seconds would have little differential effect on learning. The present study used a delay interval of five minutes. This will increase the length of activity that occurs and may

more readily show the effect of activity on learning.

Hypotheses

There are a considerable number of investigations researching the effect of time of reinforcement on human learning. The trend of these investigations questions the generalizability regarding the superiority of immediate reinforcement to all learning situations. The prior review indicates that the type of subjects or the type of learning task relegated to the subjects appear to be as important a variable as the temporal interval between response and reinforcement. Another variable which has received relatively little emphasis is the control of the pre-reinforcement activity and is further investigated in the present study.

Several investigators have attributed the results of their study to the pre-reinforcement activity and assumptions have been made as to how certain types of activities may impair or facilitate learning. But relatively few investigators have concentrated their main efforts to exploring this area. To this writer's knowledge, Champion and McBride (1962) and Jones and Bourne (1964) have conducted the only studies on delayed reinforcement in regards to verbal learning where manipulating the pre-reinforcement activity was explicitly stated as the purpose. Activity was elicited by presenting stimuli during the pre-reinforce-

ment interval with some associational value to the original one.

Jones and Bourne concluded from their study that elicitation of irrelevant activity by presenting pre-reinforcement stimuli of little associational value will interfere with performance and they also make the inference that relevant activity would facilitate performance. Champion and McBride assume that their study confirms the contention that any activity that occurs during the pre-reinforcement interval will interfere with performance. As described earlier, these two studies differ in a number of ways and further exploration appears necessary to determine the significance of the pre-reinforcement activity.

The present study places primary emphasis on the investigation of this variable and is designed to investigate the hypothesis that: The effect of time of reinforcement on learning is not due to the mere passage of time, but must be attributed to the activity which occurs during this pre-reinforcement interval. It is suggested by Jones and Bourne that the effect of relevant and irrelevant activity on human verbal learning may be measured along a continuum. Relevant activity, "rehearsing related responses", would facilitate the formation of task relevant association and as the activity becomes less relevant, there is an increasing interference effect which impairs performance.

The present study further investigates this problem and explores the applicability of such a continuum relative to the learning of meaningful verbal material. The pre-reinforcement activity of the subjects was controlled by presentation of stimuli, similar and dissimilar in meaning to the original stimulus, with instructions to learn. The specific hypotheses were:

1. If the pre-reinforcement interval activity of the subjects is controlled by presenting material of similar meaning to the material to be learned, the performance of the subjects will be facilitated relative to the subjects receiving irrelevant material.

2. If the pre-reinforcement interval of the subjects is controlled by presenting material of dissimilar meaning to the material to be learned, the performance of the subjects will be impaired, relative to the subjects receiving relevant material.

A third group was presented with no material or instruction during the pre-reinforcement interval. The purpose for this was to demonstrate the need to take into consideration the control of the activity that occurs during the pre-reinforcement interval. By comparing the controlled and non-controlled pre-reinforcement activity groups, it was assumed that the importance of the activity and not just the passage of time would be demonstrated.

Method

The two major variables explored in this study were: (1) the temporal interval between response and reinforcement; and (2) the effect of activity during the pre-reinforcement interval. The effects of immediate and delayed reinforcement and three types of activity were compared: activity as elicited by the presentation of stimuli, similar and dissimilar in meaning to the original one and also the presentation of no specifically controlled stimuli.

The effect of these two variables and the effect from their interaction, on the learning of meaningful verbal material was explored by presenting a learning situation to six groups of subjects under the following conditions:

Group A_1 - Delayed reinforcement and presentation of similar stimuli.

Group A_2 - Delayed reinforcement and presentation of dissimilar stimuli.

Group A_3 - Delayed reinforcement and no stimuli presented.

Group B_1 - Immediate reinforcement and presentation of similar stimuli.

Group B_2 - Immediate reinforcement and presentation of dissimilar stimuli.

Group B_3 - Immediate reinforcement and presentation of no stimuli.

Subjects

The subjects were 143 undergraduate students in psychology classes. The titles of the classes were General Psychology, Psychology of Adjustment, Human Growth and Development, Learning and Evaluation, and Emotional Growth of Children. Entire classes were utilized and this study utilized about half of the total subjects since it was part of a larger project. The subjects were given numbers selected from a table of random numbers and respectively assigned to one of the six experimental groups. Three groups were run per session; the order in which the six experimental conditions were to be run being selected by assignment of numbers selected from a table of random numbers.

Apparatus

An "800" Carousel slide projector was used to present the material. The learning material and the similar and dissimilar stimuli were photographed and made into 2" by 2" slides. Mimeographed question sheets were used in the test session.

Reinforcement

Reinforcement consisted of the correct answer to the multiple choice question. That is, after the subjects made their response to the stimulus, reinforcement was presented as knowledge of results. Example of stimulus phrase projected

on screen:

> Children who are shown pictures of apples as examples learn to identify an apple faster than children who are shown pictures of onions and lemons and told these aren't apples. But the children trained the latter way learn more quickly such concepts as "good sources of vitamin C" or "fresh produce." College students learn science readily by observing laboratory examples of basic principles. Later, they have difficulties with such notions as parity, anti-matter, four or more dimensions.
>
> a) Learning by example is the most effective way to teach.
>
> b) Positive instances facilitate learning.
>
> c) Negative instances interfere with complex learning, but are useful for simple discriminations.
>
> d) Learning a single concept is facilitated by all positive instances, but this interferes with the later learning of more complex concepts.

Upon reading the above, the subject makes his response.

The following reinforcement (Knowledge of Results) was then given--

> Learning a single concept is facilitated by all positive instances, but this interferes with the later learning of more complex concepts.

The reinforcements were photographed (Appendix A), made into 2" by 2" slides and presented on the screen.

Procedure

The general experimental procedure was essentially the same for each group. The subjects were presented, by means of a slide projector, with learning material in the

form of multiple choice questions (Appendix B). The subjects made a response by marking the answer they thought was correct and then immediately or five minutes after, received knowledge of results (KR). During the pre- or post-reinforcement interval, stimuli to elicit relevant and irrelevant activity were shown on the screen. The subjects were retested twenty-four hours later.

The experiment was conducted in two sessions during the subjects' regular class period. They were not told of the retest. Groups of 15 to 20 students were randomly selected from each classroom and transferred to one of three experimental rooms. The specific procedure for the two sessions was as follows (See Appendix C for the exact verbal instructions and time sequence):

1st Session. A booklet of six answer sheets was passed out to the subjects as they entered their respective experimental room and took their seats. The experimenter told the group they were participating in a learning study concerned with the effectiveness of presenting materials in different ways and that their cooperation was essential to the outcome of the study. The following instructions were then given:

> You will be shown questions on the screen one at a time. While the question is exposed, think about the question and answer and when I give the word, you will have 15 seconds to fill in the correct answer. Do not answer the question until I give

> the word, but you must fill in an answer. After you have filled in the answer, you will be instructed to tear off the sheet and turn it over. Attempt to learn the correct answer.

The subjects were then told to remain seated and refrain from talking during the experimental session.

Groups A_1, A_2 and A_3 (Delayed Reinforcement) were presented a multiple choice question and told that this was the first question. The questions were in an inductive form, that is, the subjects were to induce the principle which applied to the example presented. After one minute, the group was instructed to mark their answer, tear off the answer sheet and turn it over. Group A_1 (Irrelevant Activity) was then presented with 15 German prepositions and their English equivalence on the screen with the instructions, "Attempt to memorize these German words" (Appendix D). Group A_2 (Relevant Activity) was presented with material on the screen similar to the concept to be learned and told, "Here is some information relevant to the question, attempt to learn it" (Appendix E). Group A_3 (No controlled Activity) was presented a blank screen for five minutes and given no instructions. This sequence was replicated six times with each presentation consisting of a different principle to be learned.

The procedure for Groups B_1, B_2 and B_3 (Immediate Reinforcement) was essentially the same, however, the activity occurred during the post-reinforcement rather than

the pre-reinforcement interval.

At the end of the session, each group was given the following instructions:

> Thank you very much for your cooperation. It is very important that you do not discuss this experiment with anybody. We will be glad to discuss this experiment with you any time after Monday. Thank you again for your cooperation, you may now leave.

2nd Session. The subjects were tested twenty-four hours later in their classes. The test, consisting of two parts, was (1) a test sheet with the general title of each principle and instructions for the subjects to elaborate on or describe the principle more specifically, and (2) a test sheet with six multiple choice questions; each question consisted of the general title of a principle and four possible examples of the principle (Appendix F and G). Ten minutes was allowed for the completion of the first part and five minutes for the second part.

Results

The present study was designed to compare the relative effects on learning and retention of (1) time of reinforcement, (2) pre-reinforcement activity, and (3) the interaction of the temporal interval and activity. The hoped-for criterion was the retention of six principles. This was measured in a session twenty-four hours after the subjects were presented with the principles to be learned under the various conditions of the study. Two measures of

learning were taken: the first being the subjects' performance on describing the principles in an essay type form, using their own words, and the second was the subjects' performance on a multiple-choice questionnaire.

The scores of the individuals were combined according to their respective experimental group. An analysis of variance was used to compare their performance on the two measures of learning as well as on the total performance derived from the summation of the two measures.

Test Part I.

The subjects' performance on the six essay-type questions was evaluated according to a pre-determined criterion (Appendix H) and scored on the basis of zero, one-half, one and two points. Three judges scored the essay type answers and a measurement of the interscorer reliability was computed. The Pearson product-moment correlation was computed and interscorer correlations of greater than .9 was found among the three judges.

Analysis of variance was used to compare the differences between the experimental groups on the learning of six principles (Table 1). Presenting reinforcement (KR) immediately or after a five minute delay interval was shown to have no significant differential effect on learning. Also, the effect of eliciting activity by presenting simi-

lar and dissimilar material during the pre-reinforcement interval, as well as having no controlled material presented was insignificant: the learning performance of all three groups were equivalent. There was no significant interaction effect between the immediate or delayed KR group and the three pre-reinforcement activity conditions.

Table 1

Test Part I: Analysis of Variance of Group Performance On Six Essay Questions

Source	SS	df	MS	F
Time of reinforcement	23.76	1	23.76	2.71
Activity	33.68	2	16.84	1.92
Time of reinforcement X Activity	21.63	2	10.81	1.23
Within	1200.04	137	8.75	
Total	1279.11	142		

Test Part II

In the second part of the test, the subjects were presented with a mimeographed sheet of six multiple-choice questions. The subjects had four alternatives to choose from, a correct choice scored as one point and zero for an incorrect one. As in the first test, the analysis of variance showed no significant differences due to the effect of the two major variables or from their interaction (Table 2).

Table 2

Test Part II: Analysis of Variance of Group Performance On Six Multiple-Choice Questions

Source	SS	df	MS	F
Time of reinforcement	21.50	1	21.50	1.17
Activity	0.06	2	0.03	--
Time of reinforcement X Activity	2.80	2	1.40	--
Within	2508.48	137	18.31	
Total	2532.84	142		

Total Performance

The performance scores from Part I and II of the test were combined and the effect of the variables on the learning of principles were evaluated by means of the analysis of variance (Table 3). Analysis of the total performance score indicates that the groups learning under the conditions of immediate reinforcement did significantly better than those receiving delayed reinforcement. The superior learning performance of the immediate KR group is significant at the .05 level. There was no difference in learning due to the pre-reinforcement activity or from the interaction of time of reinforcement and activity.

Table 3

Total Performance: Analysis of Variance of Total Group Performance on Six Essay and Six Multiple-Choice Questions

Source	SS	df	MS	F
Time of reinforcement	86.66	1	86.66	6.25**
Activity	32.12	2	16.06	1.15
Time of reinforcement X Activity	44.19	2	22.09	1.59
Within	1899.19	137	13.86	
Total	2062.16	142		

** $< .05$

Discussion

The principal concern in this experiment was to investigate the relationship of learning to time of reinforcement and controlled pre-reinforcement activity. The results of this experiment support the prevalent assumption that immediate is superior to delayed KR. It also appears that the activity that occurs during the interval between response and reinforcement is an insignificant factor, not having a differential effect on the learning of meaningful verbal material. Although the hypotheses of the present study were not supported, consideration of a few factors may be of importance for the purpose of further understanding and exploring the effect of pre-reinforcement activity on learning.

Control of Activities

One of the possible factors for the superiority of immediate reinforcement and the insignificant differential effect of the three activities may have been due to the amount of material presented during the pre-reinforcement interval. Although no objective measures were taken, observations indicated that there was not enough material provided to keep the subjects occupied for the five minute delay interval. The subjects started looking around, closing their eyes, scribbling on their answer sheets and appeared to be getting tired and bored. Therefore, instead of activities varying with the respective groups, there was a general overall activity and its effect was boredom and fatigue.

It appears that the effect of this general activity was one which hindered the formation of task relevant associations and impaired the performance of the subjects receiving delayed reinforcement, thus masking the differential effects due to the type of material presented during the pre-reinforcement interval. The interfering effect from this general activity did not impair the performance of the immediate reinforcement groups since the activity occurred after the presentation of reinforcement. Due to the possibility that a general type of activity occurred in addition to the originally planned relevant, irrelevant

and no activity, the effect of various activities on delayed and immediate reinforcement may have been obscured.

Meaningfulness of the Material

It was the objective of the present research and studies of Jones and Bourne and Champion and McBride to present relevant or irrelevant activity through directed pre-reinforcement activity. Although the designs of the studies were essentially the same, the type of material to be learned differed. Whereas the present study was concerned with meaningful material, the other two concentrated on nonsense syllables and paired associations; the former requiring induction in its learning process, the latter, more rote memorization. The degree of interference from pre-reinforcement activities may be of a lesser degree on the learning of meaningful material derived through induction because the greater associational value enhances the mediation through the delay interval. This may account for the insignificant differential effect found in the present study--regardless of the type of activity. The differential effect found in the performance of the groups receiving pre-reinforcement activity in the other two studies may have been due to the type of learning material. That is, the associational value of nonsense syllables and paired associates may not be as resistant to the interference effect of intervening activity.

The Effect of Time on Retention

Another possible factor lies in the length of the temporal interval between the learning situation and retest. Stevens (1951) indicates in his review on learning and retention that the retention curve for meaningful material decelerates only slightly, so whether retention is measured immediately or after an interval of time does not seem to be of crucial importance. However, this effect may not be applicable to subjects learning under a five minute delayed reinforcement situation. The retention of groups receiving delayed reinforcement may vary significantly among the groups within the first twenty-four hours and the differential effect of the various activities on learning may only be apparent in a measure taken immediately after the learning situation. Although the present study was investigating the effect of delayed KR on what appears to be a more practical and desirable aspect of learning, i.e., retention, exploring the effect of different time intervals between test and retest may contribute to understanding what the essential mechanism is in learning situations such as the one presented in this study.

From this study, three areas for further study specific to delayed reinforcement situations become apparent. They are:

(1) Closer control of the subjects' activities or a means in which the type of activity that occurs can be directly measured, such as has been tried by measures of interpolated activities. Also, the investigations on delayed KR appear to be concerned primarily with the mechanism of learning involved in the pre-reinforcement activity and it seems that the motivational aspect of this activity would be an important area to explore and study.

(2) Systematizing investigations relative to the type of learning material so that comparisons and generalizations can be made regarding the effect of delayed reinforcement on explicitly specified learning tasks.

(3) The effect of time lapse on retention should be explored further and data be compiled so that a retention curve relative to delayed KR can be derived.

The present study brings forth numerous factors that need to be investigated so that a better understanding regarding the effect of time of reinforcement and activity on learning can be attained. Many investigators appear to overlook a number of factors and as to their possible effect

on delayed reinforcement learning situations. The need for more thorough and systematic investigations seems apparent before the general immediacy of reinforcement principle is accepted and applied to all learning situations.

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APPENDIX A

Reinforcement in the Form of Knowledge of Results for Each of the Six Responses

Reinforcement in the Form of Knowledge of Results

Reinforcement 1

The intensity of sensation is equal to the intensity of the physical stimulus squared (Multiplied by itself).

Reinforcement 2

Adolescents have trouble relating to father figures.

Reinforcement 3

When two mixable liquids which do not react chemically are placed in the same vessel, a slow mixing process occurs from the molecular motion and the liquid becomes uniform throughout.

Reinforcement 4

An argument from an accepted rule or principle to a special case, when the rule is not applicable to the special case.

Reinforcement 5

Learning a single concept is facilitated by all positive instances, but this interferes with later learning of more complex concepts.

Reinforcement 6

If you do something in a given situation, the next time you are in that situation, you will tend to do the same thing.

APPENDIX B

The Learning Material or Stimulus Presented in the Form of Multiple-Choice Questions

Stimulus: Multiple-Choice Questions

Stimulus 1

People who have stared at a 50 watt bulb report that a 100 watt bulb looks about 4 times as bright. When asked to select a light twice as bright as the 50 watt, they select one of about 70 watts. If they see a 1 watt and an 11 watt bulb, and are asked to choose a light one half way between these in brightness, they pick an 8 watt. This is an example of a psychophysical law.

a) The intensity of a visual sensation is directly proportional to the physical intensity of light.
b) The intensity of sensation is equal to the intensity of the physical stimulus squared (multiplied by itself).
c) Very strong and very weak physical intensities have a marked effect upon sensation, but moderate physical intensities produce little change.
d) Sensation increases at about half the rate of increase in physical intensity.

Stimulus 2

Phil, a typical adolescent, argues violently with his literature professor for 5 minutes. He left the room with a girl and was very jovial. Phil became very angry at a policeman who gave him a ticket for illegal parking. Phil showed great friendliness to a stray dog that barked at him. Looking at a statue of George Washington, he remarked, "why don't they get rid of that old thing!"

a) Adolescents often have nasty tempers.
b) Adolescents do not relate well with strangers.
c) Aolescents have trouble relating to father figures.
d) Adolescents are generally more cordial with those of lesser status.

Stimulus 3

If "cool-aid" is too sweet, additional water may be added to make it more drinkable.

a) When molecules of liquids are very close to each other, electrical forces produce a repulsive effect, keeping the centers of the molecules at a good distance from each other leaving the liquids in stratified layers.

b) When two mixable liquids which do not react chemically are placed in the same vessel, a slow mixing process occurs from the molecular motion and the liquid becomes uniform throughout.
c) A mixture of several liquids which do not react chemically exerts a pressure equal to the sum of the pressures which the several liquids would exert separately and whether the liquids stratify or diffuse depends on the pressure exerted.
d) When liquids containing molecules of similar charges are forced together, there is a certain amount of energy released and depending upon the total charge of the ions, a chemical reaction may occur.

Stimulus 4

This country is a democracy and dedicated to the proposition that all men are equal. Why then do we hypocritically continue to employ certain tests in admissions to colleges and universities?

a) An argument from an accepted rule or principle to a special case, when the rule is not applicable to the special case.
b) An argument when one supports a view by appealing to the endorsement of the view by someone who is not in fact an authority on the subject matter being considered.
c) When someone gives an account of what led someone (or a group) to a view and argues that since this (the account) is true, the view is false.
d) An argument wherein one tries to reply to a charge made by an opponent by making the same or similar charge against him.

Stimulus 5

Children who are shown pictures of apples as examples, learn to identify an apple faster than children who are shown pictures of onions and lemons and told these are not apples. But the children trained the latter way learn more quickly such concepts as "good sources of vitamin C" or "fresh produce." College students learn science readily by observing laboratory examples of basic principles. Later, they have difficulty with such notions as parity, antimatter, four or more dimensions.

a) Learning by examples is the most effective way to teach.
b) Positive instances facilitate learning.

c) Negative instances interfere with complex learning, but are useful for simple discriminations.
d) Learning a single concept is facilitated by all positive instances, but this interferes with later learning of more complex concepts.

Stimulus 6

A popular old way to break a wild horse for riding was to continually ride it until it was too exhausted to buck anymore. Another way was to ride it in a large mud-hold; the mud preventing the horse from bucking.

a) Pleasure and pain as consequence of our acts are the important determiners of our behavior.
b) If you do something in a given situation, the next time you are in that situation, you will tend to do the same thing.
c) If you are reinforced or rewarded for a given act, you will tend to do it the next time you are in the same situation.
d) The individual organism has expectations that the world is organized in certain ways and that certain things lead to others and will strive towards this expectation.

APPENDIX C

The Specific Temporal Intervals and Verbal Instructions for Each of the Experimental Groups--Procedure Sheet

Procedure Sheet

1) Subjects enter and take seats.

2) Pass out answer sheets.

3) Go to the front of the class and say: "You are participating in a learning study concerned with the effectiveness of presenting materials in different ways. Your cooperation is essential to the outcome of this study. Please follow the instructions as presented."

"You will be shown questions on the screen one at a time. While the question is exposed, think about the question and answers and when I give the word, you will have 15 seconds to fill in the correct answer. Do not answer the question until I give the word, but you must fill in an answer. After you have filled in the answer, you will be instructed to tear off the sheet and turn it over. Attempt to learn the correct answer."

"Remember to put your names on all sheets. This is merely for identification purposes and will not affect your grades. Remember that you are in Group _____."

"Remain seated and refrain from talking unless you are otherwise instructed. Attempt to learn the correct answer."

4) Turn out lights.

5) Problem (Follow the sequence according to whether you're in charge of the immediate or delayed group and whether you have the relevant, irrelevant or no activity group):

Delayed Group

(Time)

1 minute a) Present slide with question and say, "This is the first (second, etc.) question."

15 seconds b) Still on the same slide say, "You now have 15 seconds to mark your answer."

c) Present blank screen and say, "Please tear off the sheet and turn it over. Remember to put your name on the sheet."

5 minutes — d) Present one of the following slides:

1) Relevant material and say, "Here is some material relevant to the question. Attempt to learn"

or

2) German words and say, "attempt to learn these German words."

or

3) Nothing on the screen and say nothing.

30 seconds — e) Present correct answer and say, "This is the correct answer."

10 seconds — f) Present blank screen for 10 seconds, then start the sequence again.

Immediate Group

(Time)

1 minute — a) Present slide with question and say, "This is the first (second, etc.) question."

15 seconds — b) Still on same slide say, "You now have 15 seconds to mark your answer."

c) Present blank screen and say, "Please tear off the sheet and turn it over. Remember to put your name on the sheet."

30 seconds — d) Present correct answer and say, "This is the correct answer."

5 minutes — e) Present one of the following slides:

1) Relevant material and say, "Here is some material relevant to the question. Attempt to learn it."

or

2) German words and say, "Attempt to learn these German words."

or

3) Nothing on the screen and say nothing.

10 seconds f) Present blank screen for 10 seconds, then start the sequence again.

6) Turn on lights.

7) Go to the front and say, "Remember that this is Group ____."

"Thank you very much for your cooperation. It is very important that you do not discuss this experiment with anybody. However, we will be glad to discuss this experiment with you anytime after Monday. Thank you again for your cooperation, you may now leave."

APPENDIX D

Material Irrelevant to the Principle to be Learned for Eliciting Irrelevant Pre-Reinforcement Activity

Irrelevant Material

	German	English
1.	lachen	to laugh
2.	reden	to talk
3.	erlau'ben	allow
4.	leben	to praise
5.	schicken	send
6.	desto	the
7.	bei	with
8.	errei'chen	reach
9.	an'-zichen	put on
10.	wecken	wake up
11.	begeg'nen	meet
12.	drucken	press
13.	fressen	devour
14.	zwischen	between
15.	suchen	seek

APPENDIX E

Material Relevant to the Principle to be Learned to Elicit Relevant Pre-Reinforcement Activity

Relevant Material

Material Relevant to Stimulus 1

These four problems, detection, recognition, discrimination, and scaling, constitute the core of a segment of experimental psychology called psychophysics. The name psychophysics derives from the classical question about the relation between the physical environment and the mind. Today, modern psychophysicists are not professionally concerned with this philosophical issue of the mind-body relation, but rather with the constraints that are placed upon the behavior of a person in his judgements, actions, and so on, by the sea of physical energies that surround him.

Material Relevant to Stimulus 2

Childhood continues up to the time when the child can get on fairly well with his peers; the juvenile era begins when playmates are badly needed and are, in most ways, preferred to adults. The "eruption, due to maturation, of a need for an intimate relation with another person of comparable status" marks the beginning of pre-adolescence, a relatively brief period which ends with puberty. Adolescence is marked by a shift of interest from a person of one's own sex to one of the opposite sex, and by the patterning of adult sexual activity. At adulthood one is able, for the first time, to establish a love relationship in which the other person is almost as important as oneself.

Material Relevant to Stimulus 3

The first step in applying the scientific method is to obtain some facts, by observation and experiment. The next step is to classify and correlate the facts by general statements. If a general statement is simple in form it may be called a law of nature. If it is more complex it is called a theory. Both laws of nature and theories are called principles.

Material Relevant to Stimulus 4

In logic an argument is a group of two or more statements, one of which is affirmed on the basis of the other or others. The statement which is affirmed is called the conclusion of the argument. The statement or statements which supply the reason or reasons for affirming the conclusions are called the premises of the argument.

Material Relevant to Stimulus 5

Concepts are condensations of past experience. They bring together in a single idea, so to speak, what has been learned about properties of many different things. Take, for example, the concept tree. This concept is foreign to certain Australian tribes. The native speaks of particular objects, like the jarrah, the mulga, and the gum, but he has no word to represent what is common to them.

Material Relevant to Stimulus 6

An example of laboratory learning, on classical conditioning, is the conditioning of the eyeblink reflex in humans. If a person who is watching a dim light sees the light grow somewhat brighter, he ordinarily does not blink his eyes in response to this stimulus. If, however, he is hit in the eye by a vigorous puff of air, he does blink. The conditioning procedure consists in pairing these two stimuli, with the brightening of the light coming a fraction of a second before the puff of air. Each time this sequence occurs, the subject blinks in response to the air puff. Presently, however, he begins to blink as soon as the light changes, before the puff comes. Since the changing light now produces a blinking response which it formerly did not produce, learning has taken place. In this setup the puff, which already produced blinking, is called the unconditioned stimulus, and blinking to the puff is the unconditioned response. The increase in brightness of the light is called the conditioned stimulus, and the learned response of blinking to it is the conditioned response. The whole learning sequence is known as conditioning.

APPENDIX F

Test Part I: Essay Type Questions

TEST SHEET: PART I

Name_____Group_____No_____

Directions: Specify the principles (the ones appropriate to the experiment) that applies to the following:

1. A chemical principle - Refers to the mixing of liquids.

2. A principle of adjustment - Most adolescents have problems in their relationship with people.

3. A logical fallacy - We have laws against immorality therefore discussions of the immoral should not be allowed in college.

4. A principle of learning - A popular and old method of breaking a wild horse to ride was to ride it first in a large mud hole; the mud prevented the horse from bucking.

5. A principle of concept learning or human thinking - You can learn simple concepts such as "cat," "Potatoes," etc. by seeing examples.

6. A principle of Psychophysics - The relationship between sensations of brightness and the intensity of light source.

APPENDIX G

Test Part II: Multiple-Choice Questions

TEST SHEET: PART II

Name_____Group_____No_____

Mark the correct example of the principle you learned in the experiment.

1. A principle of learning:
   a. to stop Koke from spitting on the rug, spit on him right afterwards.
   b. to teach Young Cyclone to hang up his clothes, explain the need for orderliness and give him a toy.
   c. if little Aquinas is given to temper tantrums, attach an electrode to the child's hand and when he misbehaves, give him a small jolt.
   d. to teach little Crauch not to fear monsters, set him up in happy play and slowly reveal a small monster from a distance.

2. A principle of human thinking:

   a. children learn what "chairs" are faster by seeing sofas, dressers, etc. so they realize what a chair isn't.
   b. to teach chemistry, you need a laboratory. Learning ideas alone is not sufficient.
   c. Pube learned what "bad girls" are like by talking to his mother and aunt. He never married.
   d. Vapor had learned about airplanes by seeing airplanes only. He often confuses "flying objects", "dirigibles", and "missiles".

3. A fallacy of logic:
   a. I've known 2 redheads who were hot-tempered. All redheads are hot-tempered.
   b. the well-known Nobel winner in Physics, Dr. Void, says we are in a politically degenerate society; therefore, it must be true.
   c. if we are devoted to freedom, why have libel and slander laws?
   d. Mayor Canary is afraid of his delinquent son, Larva. Police Sgt. Stag is afraid of the Mayor. Therefore, Sgt. Stag is afraid of Larva.

4. A principle of chemistry:
   a. substances with greater molecular weight do not mix readily.
   b. the lower the atomic number of a substance the more difficult to suspend it.
   c. combustability is improved by the additions of volatile liquids of uniform density.
   d. dropping salt in coffee will make a uniform mixture --ugh.

5. A principle of adjustment or developmental psychology:
   a. Elmer dislikes professors, policemen, and chiefs of State.
   b. Fred dislikes everybody in his class.
   c. Elmo has conflicting feelings about girls.
   d. Krutch has nightmares about death and immorality.

6. A psychophysical law:
   a. most people can't detect the difference between a sound of 2 decibels and one of 3 decibels.
   b. to double the sound effects, the sound source was made 4 times as intense.
   c. if the physical sound source was doubled, the heard effect would seem 4 times as great.
   d. the more intense the sound source, the more intense the heard sound is experienced.

APPENDIX H

Criterion for Evaluating the Essay Questions of Test Part I

Criterion for Evaluating Test Part I

Score	Criteria
2	Principle is correctly stated or substantially correct (allow some incompleteness or vagueness).
1	Approximate principle, but relationship between variables not correct, or some variables left out.
½	Correct example only.
0	Wrong example, wrong principle, failure to answer.

Note: combination of answers do not get additional credit. Thus, approximate principle and a correct example receive 1 point only.